



**University of
Zurich**^{UZH}

**Zurich Open Repository and
Archive**

University of Zurich
University Library
Strickhofstrasse 39
CH-8057 Zurich
www.zora.uzh.ch

Year: 2015

**Composition of junior research groups and PhD completion rate:
disciplinary differences and policy implications**

Pull, Kerstin ; Pferdmenges, Birgit ; Backes-Gellner, Uschi

DOI: <https://doi.org/10.1080/03075079.2015.1007941>

Posted at the Zurich Open Repository and Archive, University of Zurich

ZORA URL: <https://doi.org/10.5167/uzh-128363>

Journal Article

Accepted Version

Originally published at:

Pull, Kerstin; Pferdmenges, Birgit; Backes-Gellner, Uschi (2015). Composition of junior research groups and PhD completion rate: disciplinary differences and policy implications. *Studies in Higher Education*, 41(11):2061-2077.

DOI: <https://doi.org/10.1080/03075079.2015.1007941>



**University of
Zurich^{UZH}**

Department of Business Administration

UZH Business Working Paper Series

Working Paper No. 388

**Composition of junior research groups and PhD completion rate:
disciplinary differences and policy implications**

Kerstin Pull, Birgit Pferdmenges and Uschi Backes-Gellner

February 2015

Published as: "Composition of junior research groups and PhD completion rate: disciplinary differences and policy implications." *Studies in Higher Education*, 41(2015),11: 2061-2077. By Kerstin Pull, Birgit Pferdmenges and Uschi Backes-Gellner.

DOI: dx.doi.org/10.1080/03075079.2015.1007941

University of Zurich, Plattenstrasse 14, CH-8053 Zurich,
<http://www.business.uzh.ch/forschung/wps.html>

UZH Business Working Paper Series

Contact Details

Kerstin Pull

University of Tuebingen

Department of Human Resource Management and Organization

Birgit Pferdmenges

University of Tuebingen

Department of Human Resource Management and Organization

Uschi Backes-Gellner

University of Zurich

Department of Business Administration

Composition of junior research groups and PhD completion rate: disciplinary differences and policy implications

Abstract

This paper explores the link between the composition and the performance of junior research groups. We argue that the heterogeneity-performance link depends on the type of heterogeneity (cultural vs. study field) and on the disciplinary area. We test our hypotheses on a data set of 45 junior research groups and find a U-shaped relation between cultural heterogeneity and performance in the humanities and social sciences, but no link between the two in the natural sciences. The link between study field heterogeneity and performance in the natural sciences is negative, in the humanities and social sciences study field heterogeneity and performance are not related. Interaction within the group helps reap the benefits of heterogeneity. Our results are derived in the context of junior research groups in Germany, but are generalizable to other countries and contexts where PhD education is taking part in groups.

Keywords research groups · disciplinary areas · study field heterogeneity · cultural heterogeneity · performance · group interaction

Introduction

In times where research collaborations are increasingly prevalent and widespread, the question how research team configurations affect the performance of research groups gains importance (see Subramanian, Lim, and Soh, 2013). However, existing evidence on the link between research group composition and research performance is mixed, leading Porac et al. (2004: 675) to conclude that ‘much more research’ is needed in order to better understand the relation between research team configurations and performance (see Bell and Kravitz, 2008: 301 for a similar claim).

In our paper, we argue that the mixed and partly contradictory empirical findings on the heterogeneity-performance link in research groups are likely to be the result of two countervailing effects: on the one hand, knowledge sharing within research groups will be facilitated when research group members are *similar* (e.g. with respect to their experience, scholarly background or culture), but on the other hand, the extent to which knowledge sharing will actually increase the knowledge of research groups is expanded when group members are *heterogeneous* (see Porac et al., 2004: 264). While the latter argument alludes to the potential benefits of heterogeneity, the first highlights the potential costs associated with heterogeneity. Accordingly, Milliken and Martins (1996) refer to heterogeneity as a ‘two-edged sword’, and Williams and O’Reilly (1998) call it a ‘mixed blessing’.

We argue that the benefits and costs of heterogeneity do not only depend on the type of heterogeneity, but also and crucially on the disciplinary area the research group belongs to. As Lewis, Ross, and Holden (2012) recently argued, it is important to distinguish between different disciplinary areas and to acknowledge their distinct collaborative practices. In our paper, we distinguish the natural sciences on the one hand and the humanities and social sciences on the other. It goes without saying, that these two disciplinary areas cannot fully capture the complexity of disciplinary fields in academia, but, as we will argue, they may serve as a proxy for two profoundly different processes of knowledge production—characterized by, among others, differing degrees of codification and specialization and by varying degrees to which tasks are interdependent. Concerning different types of heterogeneity, we distinguish between a research group’s heterogeneity with respect to the researchers’ study fields (‘study field heterogeneity’) and the cultural regions they originate from (‘cultural heterogeneity’).

Empirically, we analyse the heterogeneity-performance link in a sample of 45 research groups comprising junior researchers who are working on their dissertation and who are jointly supervised by a team of senior researchers, the *Graduiertenkollegs* financed by the German National Research Foundation (*DFG*). Since by nature, PhD students are faced with a complex and innovative task, our setting represents an ideal test case to investigate the heterogeneity-performance link in other innovative environments.

Graduiertenkollegs were established in the 90s as a new form of governance for PhD education in Germany where for a long time the ‘master-apprentice-model’ of PhD supervision dominated (see Sadowski and Schneider, 2010). Within that model, the responsibility for the PhD student was exclusively a matter of the supervising professor, called the “doctor father” or the “doctor mother”, respectively. The groups that we study are run by a group of cooperating researchers who jointly supervise the junior researchers, and they include a structured PhD program. Whether a group is financed by the German National Research Foundation is determined within a highly selective and competitive process. Senior researchers who apply for funding have to set up a consistent research program and a corresponding qualification program for the doctoral students. A peer review process ensures that only high quality programs are eventually financed by the German Research Foundation.

As a performance indicator we use the PhD completion rate, i.e. the number of doctorates obtained in the group per year and junior researcher—accounting for varying degrees of fluctuation between research groups. As an alternative performance measure one might have taken publications or citations generated by the group and relate them to the number of junior researchers in the group. However, publications are often only finalized at a later point in time, and meaningful citation data is also only available with a significant time lag. Further, it is not clear if and how different kinds of publications (monographs, peer-reviewed journal articles, conference proceedings) or citations should be weighted. Lastly, publication and citation patterns vary significantly even at the level of sub-disciplines. Hence, we decided to concentrate on the primary outcome of research training groups: doctoral degrees. If a group does not succeed bringing a substantial fraction of its doctoral students to complete their doctoral degrees, then this is to be regarded as problematic. The fact that the PhD completion rate varies substantially between research groups hints at completion of PhDs being a non-trivial performance indicator.

Regarding our empirical methodology, we do not only use traditional OLS regressions but also employ non-parametric LOWESS analyses which are less restrictive and unbiased concerning the underlying functional form of the investigated link. Using non-parametric analyses to investigate the heterogeneity-performance link is important since—as we will show—it is a-priori not clear which functional form to expect for the relation between heterogeneity and performance. Still, to the best of our knowledge, we are the first to employ these types of analyses to explore the link between heterogeneity and performance.

Theory

The Two Perspectives on Research Group Heterogeneity: Benefits and Costs

From a theoretical perspective, there are two different views on the heterogeneity-performance link: On the one hand, the so-called *information and decision making theory* highlights the potential benefits of heterogeneity (Gruenfeld et al., 1996; Hambrick and Mason, 1984). This resource oriented perspective assumes that people with different backgrounds or characteristics differ with respect to their cognitive skills, abilities, experiences and socialization. The variety of skills and perspectives has the potential for complementarities and a superior team performance as compared to the one of a homogeneous group. On the other hand, *social categorization theory* (Byrne, 1971) and the *similarity attraction paradigm* (Tajfel, 1974, 1981; Turner, 1975, 1987) both highlight the potential costs of heterogeneity. At the level of the individual, the similarity attraction paradigm (and related approaches, e.g., *Homophily*, see McPherson/Smith-Lovin/Cook 2001) describe the attraction of people with similar characteristics („birds of a feather flock together“). The similarity between people triggers positive emotions, because people share the same values and thus their view of the world is confirmed. Homogeneity leads to more communication, friendly relationships and social integration. At the level of the group, social categorization theory describes the fact that people define their social identity by their group affiliations. Seeking for a high self-esteem, people distinguish themselves from dissimilar people and interact less with them. In addition, social comparisons in heterogeneous groups might result in dissatisfaction that negatively affects group cohesion, communication and cooperation.

Following the *first* view (*information and decision making theory*), group heterogeneity might positively affect group performance: if a higher degree of group heterogeneity broadens the knowledge base of the group and if the additional expertise brought in by the heterogeneous group members is of use for the group production process, heterogeneity is apt to increase group performance. With respect to junior research groups, the fact that PhD students come from a different study field would clearly result in differing kinds of expertise being brought into the group (see Keller, 2001: 547; Rip, 2000; Hagedoorn, Link, and Vonortas, 2000) and might hence benefit performance. Also, adding PhD students from another cultural background might—depending on the research topic—add a new and fruitful expertise to the group (see. Bantel and Jackson, 1989; Wiersema and Bantel, 1992) or complement the individual problem solving capacities of the research group members and is hence apt to enhance performance. Thus, both study field and cultural heterogeneity might positively affect research group performance.

Following the *second* view (*similarity attraction paradigm, social categorization theory*), research group heterogeneity might negatively affect performance: in a heterogeneous group, communication between group members may be hampered, conflicts may

arise and group cohesion may be reduced. Again, the potential costs of heterogeneity in junior research groups might refer to both study field and cultural heterogeneity: the use of different (national or scientific) languages might render within-group communication more difficult and misunderstandings more likely to occur (on the role of language heterogeneity in international teams see Henderson, 2005). Correspondingly, for researchers that work on interdisciplinary tasks, Brown and Duguid (1998: 101) resume: ‘Different precepts and different attitudes [...] make interchange [...] remarkably difficult, and thus they invisibly pressure disciplines to work among themselves rather than to engage in cross-disciplinary research.’

If and to what degree research groups will actually profit from the potentially enlarged expertise in a heterogeneous group and also to what degree the downsides of heterogeneity will come into effect, will depend—as we will argue—on the disciplinary area. As we will show, the humanities and social sciences on the one hand and the natural sciences on the other differ in a multitude of aspects that are relevant for the knowledge production process and are hence apt to influence the heterogeneity-performance-link. Even though the profound differences between the two disciplinary areas have already been highlighted by Snow (1964) in his monograph on ‘the two cultures’ and are still agreed on today (see Black, and Stephan, 2008), there is ‘almost no comparative research on disciplinary differences’ (Lewis, Ross, and Holden, 2012). In what follows, we make an attempt to relate the agreed-on differences between the two disciplinary areas to the potential benefits and costs associated with heterogeneity and derive implications for the heterogeneity-performance link in different contexts.

The Diverging Benefits of Heterogeneity in the Two Disciplinary Areas

Paradigmatic nature: One first important difference between the two disciplinary areas under consideration concerns the fact that the humanities and social sciences are less paradigmatic than the natural sciences (see Biglan 1973: 207): While in the humanities and social sciences, there is a plurality of theoretical and methodical approaches (see Wanner, Lewis and Gregorio 1981: 249), the natural sciences are often dominated by one central research paradigm and hence less open to different methodologies and competing theoretical explanations (see Nuijten 2011: 198, Biglan 1973: 207). The less paradigmatic nature of the humanities and social sciences clearly increases the productive potential of heterogeneity: in the humanities and social sciences, a more heterogeneous research group has access to a larger pool of theoretical and methodological perspectives than a less heterogeneous group. Given its non-paradigmatic nature, the additional expertise brought in by PhD students with a different study field or cultural background is likely to be put to productive use. To the contrary, within the natural sciences, the spectrum of theoretical and methodological perspectives is smaller to start with, and (marginally) enriching the spectrum by adding students from another (study field or cultural) background

will not necessarily be regarded as being productive or helpful for the incumbent PhD students' research.

Degree of codification: Furthermore, knowledge in the humanities and social sciences is to a lower degree codified than knowledge in the natural sciences (see Audretsch, Lehmann and Warning 2004: 195), and as a result, implicit and tacit knowledge is more important. Much like its less paradigmatic nature, the higher relevance of tacit and implicit knowledge in the humanities and social sciences is also apt to increase the potential benefits of heterogeneity. If knowledge is less codified and rather implicit, it is harder for PhD students to access this knowledge without someone from a different study or cultural background literally bringing it to the group and sharing it. As a result, in the humanities and social sciences, a heterogeneous group might well outperform a non-heterogeneous one, whereas in the natural sciences, a more heterogeneous group will less likely have a better performance as the additional knowledge brought to the group (if of any worth at all) might also be accessed otherwise.

Degree of specialization: Lastly, also the comparatively broader and less specialized graduate education in the humanities and social sciences (see Audretsch, Lehmann and Warning 2004: 196; Hagstrom 1964: 194) and the fact that research projects are less narrowly defined (see Hagstrom 1964: 194) should each contribute to the benefits of heterogeneity in the humanities and social sciences being potentially larger than in the natural sciences. Both, a broader education and less specified research projects allow PhD students in the humanities and social sciences to better think their ways into the projects pursued by their fellow students from a different background and to give input and feedback.

To conclude, we expect the potential benefits of heterogeneity to be in general more pronounced in the humanities and social sciences than in the natural sciences.

The Diverging Costs of Heterogeneity in the Two Disciplinary Areas

Cultural specificity and the importance of language: The often culture-specific nature of research projects, the importance attached to language and wording and the "interpretative approach" to research (see Stanford University 2014) in the humanities and social sciences are likely to play a role when it comes to the link between cultural heterogeneity and performance. Unlike in the natural sciences, in the humanities and social sciences, PhD students cannot rely on a quasi-universal language (such as 'mathematics'), leaving room for language barriers to adversely affect group performance. Together with the fact that research projects in the humanities and social sciences are often culture specific and require in-depth knowledge of the specific culture to be studied, we would hence expect the costs of cultural heterogeneity to be comparatively high in the humanities and social sciences. To the contrary, the high degree of formalization as well as the concentration on mathematics as the basic 'language' in the natural sciences clearly limits the costs of

language-based misunderstandings resulting from cultural heterogeneity in the natural sciences. Concluding, we expect the costs of cultural heterogeneity to be comparatively high in the humanities and social sciences and rather low in the natural sciences.

Task interdependence and collaboration: The differing degree of task interdependence in the two disciplinary areas is expected to play a prominent role for the link between study field heterogeneity and performance. The literature consistently points to the fact that in the natural sciences, task interdependence is particularly high with Ph.D. students often literally relying on the cooperativeness of others in their research (see Warning, 2004: 395; Knorr-Cetina, 1992: 133) thus rendering cooperation not a choice, but rather a necessity (see Breneman, 1976: 26f.; Stephan, 1996: 1222; Wanner, Lewis and Gregorio, 1981: 249). Lewis, Ross and Holden (2012) distinguish between expressive ‘collaboration’ (with small ‘c’) and instrumental ‘Collaboration’ (with capital ‘C’) and find systematic differences between the disciplinary areas. Although ‘collaboration’ exists in all disciplinary areas, it is more widespread in the humanities and in the social sciences. To the contrary, in the natural sciences, ‘Collaboration’ is more widespread. While an intense level of cooperation between members of a group and more ‘Collaboration’ might enhance both the potential benefits of heterogeneity as well as its costs, Jehn, Northcraft, and Neale (1999) have shown the potentially adverse effects of heterogeneity to be more pronounced when tasks are interdependent, i.e. when group members actually rely on one another and on ‘Collaboration’ to fulfil their tasks. As a result, we expect the costs associated with study field heterogeneity to be larger in the natural sciences and lower in the humanities and social sciences.

Theoretical Expectations

As has been shown, both, benefits and costs associated with different types of heterogeneity vary between the different disciplinary areas. In the natural sciences, benefits of heterogeneity (both, cultural and study field related) are expected to be rather low as compared to the humanities and social sciences. As, at the same time, the costs associated with study field heterogeneity in the natural sciences are potentially high as a result of task interdependence, we expect study field heterogeneity in the natural sciences to be negatively linked to performance. For the humanities and social sciences, the costs associated with study field heterogeneity are expected to be low compared to the potential benefits (resulting from its less paradigmatic nature as well as its low degree of codification and specialization), and hence we postulate the heterogeneity-performance link to be positive.

With respect to cultural heterogeneity, however, our theoretical predictions are less clear: In the natural sciences, we neither expect to see substantial benefits of cultural heterogeneity nor do we expect to observe substantial costs. Hence, we postulate cultural heterogeneity and performance not to be linked in research groups from the natural

sciences. For the humanities and social sciences, the potential benefits associated with cultural heterogeneity are high—as are the potential costs. Hence, depending on the size of the effects and depending on the functional forms of the underlying benefit and cost curves, the relation between cultural heterogeneity and performance in research groups from the humanities and social sciences might be positive *or* negative. Further, it might also follow an inverted U where at first the benefits associated with heterogeneity outweigh the costs and then—after the ‘optimal’ degree of heterogeneity has been reached—the costs associated with cultural heterogeneity outweigh the benefits. Lastly, the heterogeneity-performance link might also be U-shaped if—as it has been plausibly argued by Kanter (1977a, 1977b) for the case of gender heterogeneity—it needs a certain minimum degree of heterogeneity (the so-called ‘critical mass’) for the benefits of heterogeneity to accrue. In this case, an increasing cultural heterogeneity in the humanities and social sciences might first reduce performance, but then, after some critical level of heterogeneity has been reached, increase performance again.

While our theoretical predictions on the functional form of the heterogeneity-performance link are hence not clear for each and every constellation, there is one additional implication to be drawn from the literature on group heterogeneity and performance that we will also test with the help of our data: As, Gibson and Gibbs (2006) or Ancona and Caldwell (1992) argue, an intensified communication between group members has the potential to enhance the benefits of heterogeneity and reduce its costs. Hence, we expect the extent to which communication and interaction are actively supported within a research group to positively affect group performance—irrespective of heterogeneity type and irrespective of the disciplinary area.

Data and Methods

Sample

Our empirical analysis is based on a hand-collected data set of 45 research training groups (*Graduiertenkollegs*) funded by the German National Research Foundation (DFG). Our data set comprises all research groups from the humanities and social sciences and the natural sciences that were in their second funding period and had submitted an application for a third funding period between October 2004 and October 2006. There are 45 research groups in our data set, 22 research groups belong to the humanities and social sciences and 23 belong to the natural sciences. The research groups in our data set comprise more than 1,000 junior researchers. On average, there are 24 junior researchers in a research group, varying between 12 and 38 junior researchers. These are led and supervised by a group of, on average, 12 senior researchers, with the number of senior researchers ranging from 6 to 21.

Measures

Performance: The performance of a research training group is measured by the doctoral completion rate. The doctoral completion rate is equivalent to the number of doctorates obtained in the research group per year and junior researcher—additionally accounting for varying degrees of fluctuation. While one might argue that writing a doctoral thesis is not a team output, Lewis, Ross, and Holden (2012) emphasize the importance of social interaction for the process of research even for sole authored publications. Also, Stephan (1996) as well as Carayol, and Matt (2004) have argued the scientific environment to be increasingly important, with the trend towards more collaboration manifesting itself—among others—in a steady increase of co-publications (see Rigby and Edler, 2005: 785; Adams et al., 2005) and an increased significance of acknowledgements (Giles and Councill, 2004: 17603f.). Thus, completing a dissertation is also to be regarded as being the result of efficient group processes (on the role of networks for doctoral students see also Pilbeam, Lloyd-Jones, and Denyer 2013)—especially in the context of research training groups. In our analysis, we regard the group of fellow PhD students as representing one significant part of a young researchers’ scientific environment. The information on the doctoral completion rate is taken from the compulsory report handed in by the research groups when applying for a third funding period (i.e., the research groups can be expected to fully report their successes in order to increase the likelihood to be granted the third funding period).

Heterogeneity: To capture heterogeneity, we use Blau’s (1977) heterogeneity index defined as

$$H = 1 - \sum_{i=1}^n s_i^2$$

with n representing the total number of categories of a variable, and s_i representing the fraction of team members falling into category i . The figures were standardized on the interval $[0,1]$ with ‘1’ representing maximum heterogeneity (see Alexander et al., 1995: 1466). We distinguish between two different types of heterogeneity. For our measure of study field heterogeneity, we distinguish 22 different study fields according to the International Standard Classification of Education (ISCED). For our measure of cultural heterogeneity, we distinguish nine cultural regions according to the classification by Huntington (1996). The heterogeneity data was taken from different sources: the information on junior researchers’ study field was taken from the compulsory reports handed in by the research groups. In those cases where the reports did not contain the required information, we sent a letter to the speaker of the research group (i.e. to the senior researcher that organizes the group) and asked him or her for the required information. The information on junior researchers’ nationality came from a survey undertaken by the German National Research Foundation.

Group interaction: In a last step of our empirical analysis, we account for two potentially moderating factors with respect to the extent to which group interaction is institutionalised and supported: (a) the time research group students jointly spent in research seminars giving them the opportunity to interact and (b) the commitment and engagement of supervisors as judged by research group students indicating the intensity of interaction between junior and senior researchers. Both variables were collected in an encompassing online survey of the junior researchers in the research groups. The measures were as follows: The time jointly spent in research group seminars was measured by the number of extra hours per term research group students spent as participants in research seminars organized by the research group (on top of the compulsory course program offered by the research training group). The commitment of the senior researchers as the supervisors of the groups was measured by the following question: ‘How do, in your opinion, research group students in your research group assess the commitment of the supervising senior researchers in the research group?’ Answers on this latter question reached from ‘very high’ (coded 4), ‘high’ (coded 3), ‘rather low’ (coded 2) to ‘low’ (coded 1).

Methods

We explored the heterogeneity-performance link by using the log of the doctoral completion rate as the dependent variable and applying traditional OLS and non-parametrical LOWESS analyses. We used OLS instead of TOBIT because the log of the doctoral completion rate takes a wide range of values between 0 and 1 but hardly the boundaries. We use non-parametric locally weighted scatterplot-smoother (LOWESS) analyses predicting performance by weighted regressions (see Hamilton, 2006: 219f; Cleveland, 1994). LOWESS applies to situations in which the classical linear and nonlinear regressions are overstrained. With the help of a set of local regressions, the smoother can find the (approximate) function that—to the best possible extent—represents the bivariate relationship. The process is considered for localized subsets of data as each smoothed value is determined by neighboring data points defined within the span. The weighting results from a defined regression weight function for the data points contained within the span (for more details see Cleveland, 1994). We apply the non-parametric locally weighted scatterplot-smoother analyses because of the essential advantage of this method: It does not require the specification of a global function for the whole dataset, and it also applies for situations in which no clear theoretical model exists. Its less restrictive character with respect to the functional form of the heterogeneity-performance link makes us more confident to have detected the ‘true’ functional form of the heterogeneity-performance link in the different disciplinary areas than with using parametric methods such as OLS.

Results

Descriptives

Table 1 displays the means, standard deviations, minimum and maximum values for all variables, and Table 2 delivers the correlations—separately for the two disciplinary areas. Our data only displays one significant correlation: In the natural sciences, study field heterogeneity is negatively related to the doctoral completion rate ($r=-0.41^*$). Standard tests indicate that there are no problems of multi-collinearity.

(Tables 1 and 2)

The Link between Study Field Heterogeneity and Performance

Table 3 shows the results of our OLS analysis for study field heterogeneity, separately for the humanities and social sciences (Panel A) and for the natural sciences (Panel B) each time testing for both, (i) a linear and (ii) a quadratic relation. Other than expected, for the humanities and social sciences, we find no clear relation between study field heterogeneity and performance. Also, neither of the two estimations is statistically significant. Apparently, it does not play a role for the performance of research groups in the humanities and social sciences whether they are composed of researchers from different study backgrounds or not. In the natural sciences, to the contrary, we find clear evidence of the expected negative linear relation between study field heterogeneity and research performance. That is, research groups from the natural sciences suffer from an increased heterogeneity with respect to the study background of researchers. A ‘one-size-fits-all’ approach in research funding policy where more study background heterogeneity is typically honoured and valued, irrespective of the disciplinary field, will hence prove highly dis-functional.

(Table 3)

To further validate the detected negative link between study field heterogeneity and performance in the natural sciences, we employ non-parametric LOWESS analyses (see Figure 1). Our findings support the view that the link between study field heterogeneity and performance in the natural sciences is negative: the more heterogeneity, the lower performance.

(Figure 1)

The Link between Cultural Heterogeneity and Performance

In a next step, we analyse the link between cultural heterogeneity and performance, again by first using conventional OLS regression analyses. Table 4 shows the results of our analysis, both for the humanities and social sciences (Panel A) and for the natural sciences (Panel B).

(Table 4)

All estimations are non-significant. As expected, there is no clear relation between cultural heterogeneity and research performance in the natural sciences. For the humanities and social sciences, our results hint a U-shaped relation between cultural heterogeneity and research performance with performance reaching a minimum at intermediate levels of cultural heterogeneity, and only at very high levels of heterogeneity, surpassing the performance level of culturally homogenous groups. However, since the corresponding estimation is statistically non-significant, we further investigate the functional form of the respective link by applying non-parametric LOWESS analyses. As Figure 2 shows, also the non-parametric analysis hints at the heterogeneity-performance link being U-shaped.

(Figure 2)

Group Interaction and the Heterogeneity-Performance-Link

In a last step of our empirical analysis we attempt to find out whether there are ways for those that run junior research groups to better reap the benefits of heterogeneity by taking appropriate organizational precautions. Referring to Gibson and Gibbs (2006) or Ancona and Caldwell (1992) who argue communication and interaction to potentially enhance the upside potential of heterogeneity, we analyse whether the extent to which group interaction is actively promoted and institutionalised might act as a moderator of the heterogeneity-performance link (on the moderating role of communication and interaction see also, Smith et al., 1994; Hambrick and D'Aveni, 1992 or Ely, Padavic and Thomas, 2012).

Figure 3 explores the moderating effect of institutionalised group interaction on the negative link between study field heterogeneity and performance in the natural sciences with the help of the LOWESS analysis. In the left panel, we differentiate between research groups where students spend comparatively few hours in joint seminars and research groups where students spend comparatively many hours in joint seminars. In the right panel, we differentiate between research groups where students rate their supervisors' engagement to be rather low and research groups where students rate their supervisors' engagement to be rather high. Judging supervisors to be more or less engaged (right panel)

appears to positively affect the heterogeneity-performance link. That is, in research groups where supervisors are judged to be rather engaged, the adverse effects of study field heterogeneity are apparently dampened.

In Figure 4, we explore the effect of institutionalised group interaction on the link between cultural heterogeneity and performance in the humanities and social sciences. As can be seen, in research groups where the junior and senior researchers meet more often (left panel) and where the senior researchers are judged to be more engaged (right panel), heterogeneous research groups catch up earlier with homogeneous ones or even surpass them in their research performance.

(Figures 3 and 4)

Discussion and conclusion

In our study we explore the heterogeneity-performance link in junior research groups and contribute to the recent literature that investigates the role of research team composition for research productivity. We focus on research group heterogeneity with respect to the study fields of the junior researchers and with respect to the cultural regions they come from. We show theoretically and empirically that the effects of these different types of heterogeneity depend on the disciplinary area (natural sciences vs. humanities and social sciences). In particular, we find a negative link between study field heterogeneity and performance in the natural sciences, but no relation between study field heterogeneity and performance in the humanities and social sciences. That is, study field heterogeneity does not matter (neither for the good nor the bad) in research groups from the humanities and social sciences. Apparently, the potential benefits arising from study field heterogeneity in a disciplinary area with, among others, a comparatively low degree of codification and specialization, are compensated by the potential costs arising from different ‘languages’ associated with the different study fields. To the contrary, in the natural sciences, the costs associated with study field heterogeneity that, among others, result from the high degree of task interdependence, outweigh any potential benefits. Further, we find evidence for a U-shaped relation between cultural heterogeneity and performance in the humanities and social sciences, while in the natural sciences, cultural heterogeneity and performance are not related. That is, in the natural sciences, researchers’ cultural background does not matter for a team to function well and be productive whereas research groups in the humanities and social sciences are highly productive if they come from the same cultural background or if they come from a broad range of different cultural backgrounds. A ‘medium’ degree of cultural diversity, however, does not seem to be helpful. One potential explanation for this observation is that the costs associated with cultural heterogeneity in the humanities and social sciences (e.g. resulting from cultural specificity and the

importance of language and wording) are only outweighed by the potential benefits of heterogeneity if a ‘critical mass’ of heterogeneity has been reached. Lastly, we find that the extent to which group interaction is promoted and institutionalised (e.g., by regular seminars or through active supervision) helps to reap the benefits of heterogeneity. Since the disciplinary areas represent different underlying knowledge production processes, we derive general implications and conclusions from our analysis that will hopefully inspire further studies on the heterogeneity-performance link in other higher education and innovative contexts.

Our research makes three contributions. *First*, we contribute to the literature on potential moderating factors of the heterogeneity-performance link. We do so by analysing the potential benefits and costs of heterogeneity explicitly taking into account the specificities of the knowledge production processes that are characteristic for a disciplinary area. Further differentiating between two different types of heterogeneity, we find evidence for the heterogeneity-performance link to differ between types of heterogeneity and between disciplinary areas. Furthermore, we provide evidence for a moderating role of institutionalised group interaction, hinting at the potential to actively avoid or reduce the negative effects of heterogeneity while still keeping the positive effects—if adequate organizational measures are taken.

Our *second* innovation which might inspire future work on the subject is our use of non-parametric analyses when exploring the functional form of the heterogeneity-performance link. Unlike traditional OLS regressions, the additionally performed non-parametric LOWESS analyses allow us to investigate the heterogeneity-performance link without prescribing what its functional form will be like. To the best of our knowledge, such non-parametric analyses have not been used as yet to explore the functional form of the heterogeneity-performance link.

Thirdly, our study on research groups in two different disciplinary areas allows us to derive general implications and conclusions that go beyond our particular field of application of research training groups in Germany. While our analysis does not apply to situations where a doctoral dissertation is supervised on a one-to-one basis (‘master-apprentice-model’), we are confident that our results can well be generalized to situations where doctoral dissertations are supervised by advisory committees, where PhD students are teamed up in graduate schools or laboratories, and where they participate in structured PhD programs. The US system of PhD education is a typical example of this model, but many European countries have also moved or now move in this direction. Structured doctoral programmes emerged in many European countries even before the Bologna-Process, but since the Bergen-Communiqué proclaimed the need for structured doctoral programs in European higher education in 2005, the introduction of structured PhD programs took up speed. According to the European University Association (2007: 9), 30% of the European higher education institutions surveyed have established some kind of doctoral, graduate or research school. Only in five European countries that responded to an

accompanying country survey, higher education institutions *solely* rely on traditional individual PhD supervision (Bosnia-Herzegovina, Cyprus, Georgia, Malta, and Montenegro). In all other 32 European countries that responded to the survey, higher education institutions at least additionally rely on structured PhD programs and they increasingly do so. So our results apply for an increasing number of institutions and programs worldwide.

But what are our *practical implications*? Our practical implications are basically on two levels: At the policy level, the general lesson is that a ‘one-size-fits-all’ approach in research policy is not appropriate (see also Lewis, Ross and Holden 2012). While in one disciplinary area, a specific type of heterogeneity might be productive, in another it might not. Hence, it is by no means functional to formulate a general quest for an increased internationality or an increased interdisciplinarity in research groups when, e.g., making funding decisions. Rather, national (and supra-national) policy frameworks should tailor their funding policies to the specificities of the disciplinary areas, and future research should further explore these specificities. At the level of research training groups or doctoral schools, our analysis implies that the extent to which group interaction is institutionalised and supported, crucially affects the heterogeneity-performance link—primarily by mitigating potential adverse effects, but also by enhancing its productive potential. This is good news for organizations that set up heterogeneous groups in an attempt to reap the benefits of heterogeneity. These should care for repeated and institutionalized interaction among PhD students and between PhD students and senior researchers or supervisors to enhance communication and exchange within the group.

References

- Adams, J.D., G.C. Black, J.R. Clemmons, and P.E. Stephan. 2005. “Scientific Teams and Institutional Collaborations: Evidence from U.S. Universities, 1981-1999.” *Research Policy* 34: 259-285.
- Alexander, J., B. Nachols, J. Bloom, and S.-Y. Lee. 1995. “Organizational Demography and Turnover: An Examination of Multiform and Nonlinear Heterogeneity.” *Human Relations* 48: 1455-1480.
- Ancona, D.G., and D.F. Caldwell. 1992. “Bridging the Boundary: External Activity and Performance in Organizational Teams.” *Administrative Science Quarterly* 37: 634-665.
- Audretsch, D.B., E.E. Lehmann, and S. Warning. 2004. “University Spillovers: Does the Kind of Science Matter?” *Industry and Innovation* 11: 193-206.

- Bantel, K.A., and S.E. Jackson. 1989. "Top Management and Innovations in Banking: Does the Composition of the Top Team Make a Difference?" *Strategic Management Journal* 10: 107-124.
- Bell, M.P., and D.A. Kravitz. 2008. "From the Guest Co-Editors: What Do We Know and Need to Learn About Heterogeneity Education and Training?" *Academy of Management Learning & Education* 7: 301-308.
- Biglan, A. 1973. "Relationships between Subject Matter Characteristics and the Structure and Output of University Departments." *Journal of Applied Psychology* 57: 204-213.
- Black, G.C., and P.E. Stephan. 2008. "The Economics of University Lab Science and the Role of Foreign Graduate Students and Postdoctoral Scholars." Andrew Young School of Policy Studies: Working Paper 2008-12-2. retrieved on November 13th 2014: <http://ayspsprodweb.gsu.edu/drupal/sites/default/files/documents/uwrg/files/Economics%20University%20Lab.pdf>
- Blau, P.M. 1977. *Inequality and Heterogeneity*. New York: Free Press.
- Breneman, D.W. 1976. "The Ph.D. Production Process." In *Education as an Industry* edited by J.T. Froomkin, D.T. Jamison, and R. Radner, 3-52. Cambridge, MA: Ballinger.
- Brown, J.S., and P. Duguid. 1998. "Organizing Knowledge." *California Management Review* 40: 90-111.
- Byrne, D. 1971. *The Attraction Paradigm*. New York: Academic Press.
- Carayol, N., and M. Matt. 2004. "Does Research Organization Influence Academic Production? Laboratory Level Evidence from a Large European University." *Research Policy* 33: 1081-1102.
- Cleveland, W.S. 1994. *The Elements of Graphing Data*. Revised Edition. Summit: Hobart Press.
- Ely, R.J., I. Padavic, and D.A. Thomas. 2012. "Racial Diversity, Racial Asymmetries, and Team Learning Environment: Effects on Performance." *Organization Studies* 33: 341-362.
- European University Association. 2007. "Doctoral Programmes in Europe's Universities: Achievements and Challenges." Report Prepared for European Universities and Ministers of Higher Education. Brussels. <http://www.voced.edu.au/content/ngv64865>

Gellert, C. 1993. „The Conditions of Research and Training in Contemporary German Universities.” In *The Research Foundations of Graduate Education. Germany, Britain, France, United States, Japan* edited by B.R. Clark, 45-66. Berkeley: University of California Press.

Gibson, C.B., and J.L. Gibbs. 2006. “Unpacking the Concept of Virtuality: The Effects of Geographic Dispersion, Electronic Dependence, Dynamic Structure, and National Heterogeneity on Team Innovation.” *Administrative Science Quarterly* 51: 451-495.

Giles, C.L., and I.G. Councill. 2004. “Who Gets Acknowledged: Measuring Scientific Contributions through Automatic Acknowledgment Indexing.” *Proceedings of the National Academy of Sciences*, 101: 17599-17604.

Gruenfeld, D.H., E.A. Mannix, K.Y. Williams, and M.A. Neale. 1996. “Group Composition and Decision Making: How Member Familiarity and Information Distribution Affect Process and Performance.” *Organizational Behavior and Human Decision Processes* 67: 1-15.

Hagedoorn, J., A.N. Link, and N.S. Vonortas. 2000. “Research Partnerships.” *Research Policy* 29: 567-586.

Hagstrom, W.O. 1964. “Anomy in Scientific Communities.” *Social Problems*, 12: 186-195.

Hambrick, D.C., and R.A. D’Aveni. 1992. “Top Team Deterioration as Part of the Downward Spiral of Large Corporate Bankruptcies.” *Management Science* 38: 1445-1466.

Hambrick, D.C. and Ph. A. Mason. 1984. “Upper Echelons: The Organization as a Reflection of its Top Managers.” *Academy of Management Review*, 9: 193-206.

Hamilton, L.C. 2006. *Statistics with STATA*. Belmont, CA: Thomson, Brooks/Cole.

Henderson, J.K. 2005. “Language Heterogeneity in International Management Teams.” *International Studies of Management & Organization* 35: 66-82.

Huntington, S.P. 1996. *The Clash of Civilizations and the Remaking of World Order*. New York: Simon & Schuster.

Jehn, K.A. and K. Bezrukova. 2004. “A Field Study of Group Heterogeneity, Workgroup Context, and Performance.” *Journal of Organizational Behavior* Special Issue ‘Heterogeneity and the Workplace’ 25: 703–729.

- Jehn, K.A., G.B. Northcraft, and M.A. Neale. 1999. "Why Differences Make a Difference: A Field Study of Heterogeneity, Conflict and Performance in Workgroups." *Administrative Science Quarterly*, 44, 741-763.
- Kanter, R. 1977a. *Men and Women of the Organization*. New York: Basic Books.
- Kanter, R. 1977b. "Some Effects of Proportions on Group Life: Skewed Sex Ratios and Responses to Token Women." *American Journal of Sociology* 82: 965-990.
- Keller, R.T. 2001. "Cross-functional Project Groups in Research and New Product Development: Heterogeneity, Communications, Job Stress, and Outcomes." *Academy of Management Journal* 44: 547-555.
- Knorr-Cetina, K. 1992. "The Couch, the Cathedral, and the Laboratory: On the Relationship between Experiment and Laboratory Science." In *Science as Practice and Culture*, edited by A. Pickering, 113-138. Chicago, London: University of Chicago Press.
- Lewis, J., S. Ross, and T. Holden. 2012. "The How and Why of Academic Collaboration: Disciplinary Differences and Policy Implications." *Higher Education* 64: 693-708.
- McPherson, M., L. Smith-Lovin, and J.M. Cook. 2001. "Birds of a Feather: Homophily in Social Networks." *Annual Review of Sociology* 27: 415-444.
- Milliken, F.J., and L.L. Martins. 1996. "Searching for Common Threads: Understanding the Multiple Effects of Heterogeneity in Organizational Groups." *Academy of Management Review* 21: 402-433.
- Nuijten, E. 2011. "Combining Research Styles of the Natural and Social Sciences in Agricultural Research." *NJAS - Wageningen Journal of Life Sciences* 57: 197-205.
- Pilbeam, C., G. Lloyd-Jones, and D. Denyer. 2013. "Leveraging Value in Doctoral Student Networks through Social Capital." *Studies in Higher Education* 38: 1472-1489.
- Porac, J.F., J.B. Wade, H.M. Fischer, J. Brown, A. Kanfer, and G. Bowker. 2004. "Human Capital Heterogeneity, Collaborative Relationships, and Publication Patterns in a Multidisciplinary Scientific Alliance: a Comparative Case Study of two Scientific Teams." *Research Policy* 33: 661-678.
- Rigby, J. and J. Edler. 2005. "Peering inside Research Networks: Some Observations on the Effect of the Intensity of Collaboration on the Variability of Research Quality." *Research Policy* 34: 784-794.

- Rip, A. 2000. "Fashions, Lock-ins and the Heterogeneity of Knowledge Production." In *The Future of Knowledge Production in the Academy* edited by J. Merle, and T. Hellström, 28-39. Buckingham: Open University Press.
- Sadowski, D., and P. Schneider. 2010. "The Impact of New Public Management Instruments on PhD Education." *Higher Education* 59: 543–565.
- Smith, K.G., K.A. Smith, J.D. Olian, H.P. Sims, Jr., D.P. O'Bannon, and J.A. Scully. 1994. "Top Management Team Demography and Process: The Role of Social Integration and Communication." *Administrative Science Quarterly* 39: 412-438.
- Snow, C.P. 1964. *The two Cultures: and a Second Look. An Expanded Version of the Two Cultures and the Scientific Revolution*. Cambridge: University Press.
- Stanford University. 2014. "How is Humanities Research Conducted." retrieved on October 23rd 2014. <http://shc.stanford.edu/how-humanities-research-conducted>
- Stephan, P.E. 1996. "The Economics of Science." *Journal of Economic Literature* 34: 1199-1235.
- Subramanian, A.M., K. Lim, and P.-H. Soh. 2013. "When Birds of a Feather don't Flock Together: Different Scientists and the Roles they Play in Biotech R&D Alliances." *Research Policy* 3: 595-612.
- Tajfel, H. 1974. "Social Identity and Intergroup Behaviour." *Social Science Information* 13: 65-93.
- Tajfel, H. 1981. *Human Groups and Social Categories: Studies in Social Psychology*. Cambridge: Cambridge University Press.
- Turner, J.C. 1975. "Social Comparison and Social Identity: Some Comparisons for Intergroup Behavior." *European Journal of Social Psychology* 5: 5-34.
- Turner, J.C. 1987. *Rediscovering the Social Group: A Social Categorization Theory*. Oxford: Blackwell.
- Wanner, R.A., L.S. Lewis, and D.I. Gregorio. 1981. "Research Productivity in Academia: A Comparative Study of the Sciences, Social Sciences and Humanities." *Sociology of Education* 54: 238-253.
- Warning, S. 2004. "Performance Differences in German Higher Education: Empirical Analysis of Strategic Groups." *Review of Industrial Organization* 24: 393-408.

Wiersema, M.F., and K.A. Bantel. 1992. "Top Management Team Demography and Corporate Strategic Change." *Academy of Management Journal* 35: 91-121.

Williams, K.Y., and Ch.A. O'Reilly. 1998. "Demography and Heterogeneity in Organizations: A Review of 40 Years of Research." *Research in Organizational Behavior* 20: 77-140.

Table 1: Means, standard deviations, minimum and maximum values

	Panel A: Humanities and social sciences				Panel B: Natural sciences			
	mean	s.d.	Min	Max	mean	s.d.	Min	Max
Doctoral completion rate	.13	.09	.00	.30	.17	.11	.00	.38
Study field heterogeneity	.34	.18	0	.66	.21	.27	0	.79
Cultural heterogeneity	.18	.18	0	.68	.33	.21	0	.71

Source: Own data.

Table 2: Correlations

	Panel A: Humanities and social sciences		Panel B: Natural sciences	
	(1)	(2)	(1)	(2)
(1) Doctoral completion rate	1		1	
(2) Study field heterogeneity	-0.12	1	-0.41*	1
(3) Cultural heterogeneity	-0.14	-0.21	0.17	-0.07

Source: Own data.

Table 3: Study Field Heterogeneity and Research Performance

	Panel A: Humanities and social sciences		Panel B: Natural sciences	
	(i)	(ii)	(i)	(ii)
Study field heterogeneity	-1.30	-5.61	-3.78***	4.54
Study field heterogeneity ²		6.98		-11.50***
Constant	-4.51***	-4.08***	-4.00***	-4.40***
R ²	0.04	0.08	0.44	0.63
Prob χ^2	0.39	0.48	0.00	0.00
N	22		23	

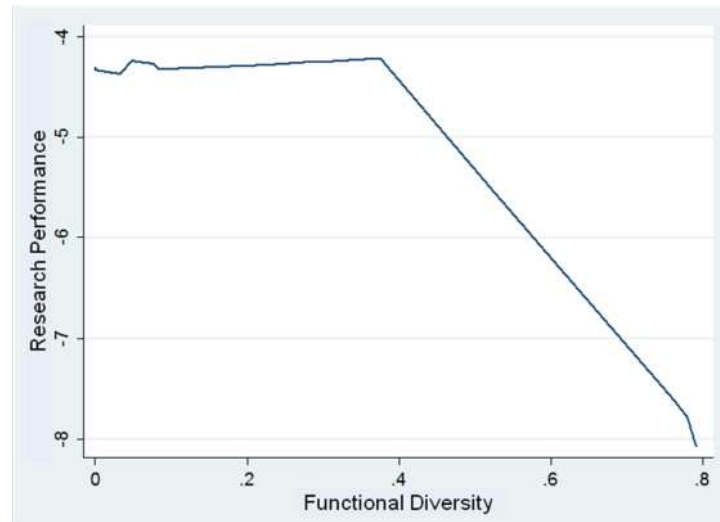
Source: Own data.

Table 4: Cultural Heterogeneity and Research Performance

	Panel A: Humanities and social sciences		Panel B: Natural sciences	
	(i)	(ii)	(i)	(ii)
Cultural heterogeneity	-1.21	-7.00*	1.15	6.12
Cultural heterogeneity ²		10.83*		-7.19
Constant	-4.73***	-4.38***	-5.15***	-5.71***
R ²	0.03	0.17	0.02	0.05
Prob χ^2	0.42	0.18	0.49	0.60
N	22		23	

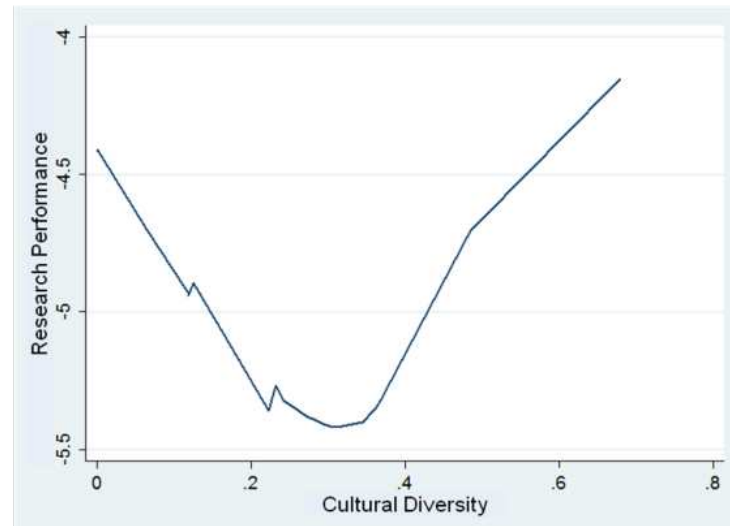
Source: Own data.

Figure 1: Study Field Heterogeneity and Research Performance in the Natural Sciences: Results from the Non-parametric Analysis (LOWESS)



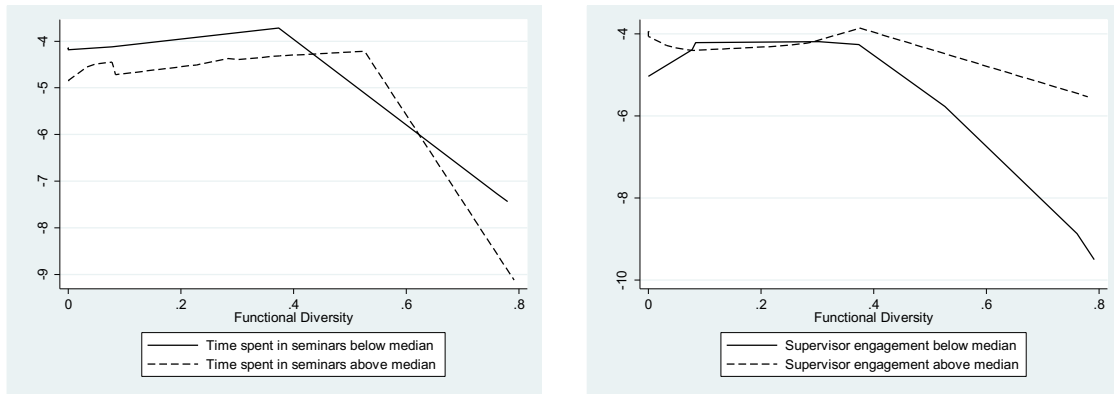
Source: Own data.

Figure 2: Cultural Heterogeneity and Research Performance in the Humanities and Social Sciences: Results from the Non-parametric Analysis (LOWESS)



Source: Own data.

*Figure 3: Study Field Heterogeneity and Performance in the Natural Sciences:
The Moderating Role of Institutionalised Group Interaction (LOWESS)*

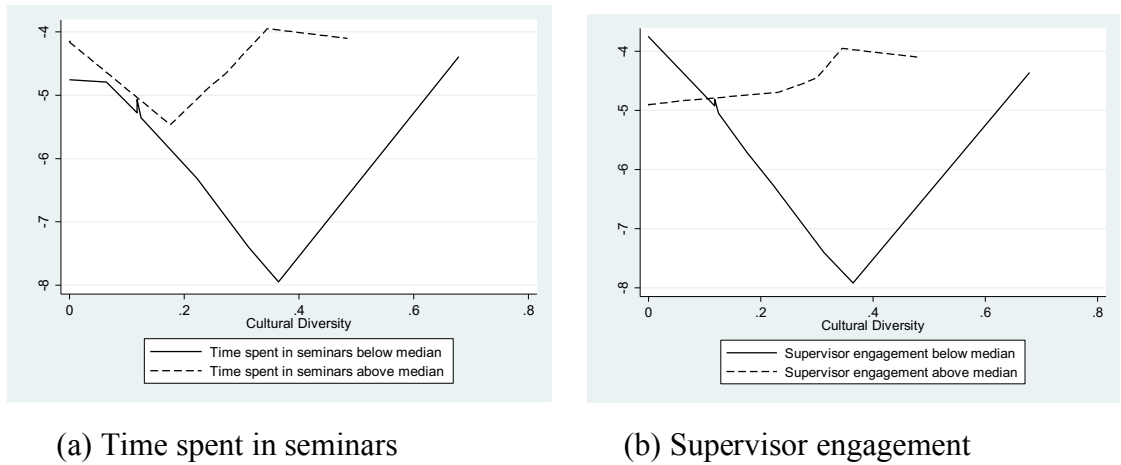


(a) Time spent in seminars

(b) Supervisor engagement

Source: Own data.

Figure 4: Cultural Heterogeneity and Research Performance in the Humanities and Social Sciences: The Moderating Role of Institutionalised Group Interaction (LOWESS)



Source: Own data.